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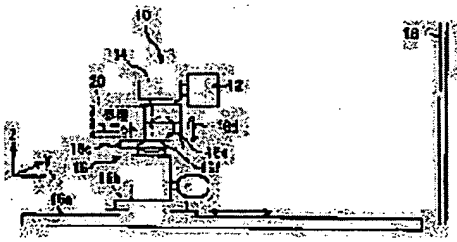
(54) DEVICE FOR DECIDING INTERNAL PARAMETERS OF CAMERA



(57)Abstract:

PROBLEM TO BE SOLVED: To precisely decide an inner parameter by correcting a plurality of image signals stored, based on a calculated lens distortion center and lens distortion quantity and deciding the internal parameters of a camera based on a plurality of corrected image signals.

SOLUTION: A processing unit 20 sets the reference position of a camera 10 based on the positions of the camera 10 and a lattice point, stores an image signal obtained by photographing the lattice point from the camera 10 which is set in the reference position, measures the coordinates of the lattice point based on the stored image signal and calculates lens distortion quantity. The processing unit 20 and an X-stage 16a move the camera to a forward direction or a backward direction from the reference position, which is set and stores a plurality of image signals obtained by photographing. The processing unit 20 corrects a plurality of stored image signals based on three calculated lens distortion center and lens distortion quantity and decides the internal parameter of the camera 10, based on a

plurality of corrected image signals.

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CLAIMS

[Claim(s)]

[Claim 1] It is equipment which determines an internal parameter of a camera which includes lens distortion at least. a. The 1st picture signal store means which stores a picture signal which photos a known lattice point pattern and is acquired, b. A lens distortion center calculation means to compute a lens distortion center of said camera based on said stored picture signal, c. It is based on a location of said camera adjusted based on said computed lens distortion center, and a lattice point pattern. A criteria location means to set up a criteria location of said camera, the 2nd picture signal store means which stores a picture signal which photos said lattice point and is acquired from a camera set as the d. aforementioned criteria location, e. An amount calculation means of distortion to compute the amount of lens distortion by measuring

a coordinate of the lattice point based on said stored picture signal, f. Said camera is moved to before or the back from said set-up criteria location. The 3rd picture signal store means which stores two or more picture signals photoed and acquired, g. A lens rectification means to correct said two or more stored picture signals based on said lens distortion center and amount of lens distortion which were computed, And internal parameter decision equipment of a camera characterized by having a parameter decision means to determine an internal parameter of said camera based on two or more picture signals by which the h. aforementioned correction was made.

DETAILED DESCRIPTION

[Detailed Description of the Invention]

[0001]

[The technical field to which invention belongs] This invention relates to what amends distortion of an image with a lens and determined the internal parameter proper in more detail about the internal parameter decision equipment of a camera.

[0002]

[Description of the Prior Art] Generally, when measuring the location (or clearance) from the image of a camera, for example, a CCD camera, to the candidate for photography, camera parameters, such as magnitude of 1 pixel at the time of carrying out daisy TAIZU of the focal distance of a camera, an image center, and the CCD image or an aspect ratio, influence the accuracy of measurement greatly.

[0003] Conventionally, these camera parameters are computed as shown in a Provisional-Publication-No. 63-No. 136892 official report. That is, the n lattice points (n>=4) used as the criteria prepared beforehand are photoed, and it asks for two or more groups of the coordinate (ai, bi) on the three dimension of the lattice point i (i= 1, 2, .. n) (object frame on a plane 12), and the coordinate on an image (pi, qi).

[0004] Subsequently, the coordinate on the three dimension, the coordinate on the image for which it asked by count from the known parameter, and the coordinate on the actually measured image have determined focal distance f, optical-axis point (amount of offset) (fp, fq), and aspect ratio s that the equivalent or its difference will become the smallest at the strange parameter and the concrete target.

[0005]

[Problem(s) to be Solved by the Invention] However, by the above-mentioned conventional technique, sufficient precision of what can ask coincidence for these interior parameter and the parameter of a camera location and a posture from one photography and measurement (decision) was not able to be acquired.

[0006] That is, in case the incident light from the candidate for photography penetrates a lens and is generally reflected in an image, there is orientation distorted to image center (or image circumference) approach depending on the angle with which incident light penetrates a lens from a lens center line around an image.

[0007] In the conventional technology, since each parameter was determined without amending distortion of an image with this lens, the internal parameter of a camera was not able to be determined correctly. Moreover, even when a correction term was put in, since other parameters and coincidence were asked, it was difficult [it / the amount of distortion was minute compared with the amount of other parameters, and] to acquire an exact value.

[0008] Therefore, it is in the purpose of this invention offering the internal parameter decision equipment of the camera which is to cancel above-mentioned un-arranging, amends distortion of an image with a lens, and determined the internal parameter correctly.

[0009]

[Means for Solving the Problem] In order to solve the above-mentioned purpose, as shown in claim 1 term, it is equipment which determines an internal parameter of a camera which includes lens distortion at least. The 1st picture signal store means which stores a picture signal which photos a known lattice point pattern and is acquired, A lens distortion center calculation means to compute a lens distortion center of said camera based on said stored picture signal, It is based on a location of said camera adjusted based on said computed lens distortion center, and a lattice point pattern. A criteria location means to set up a criteria location of said camera, the 2nd picture signal store means which stores a picture signal which photos said lattice point and is acquired from a camera set as said criteria location, An amount calculation means of distortion to measure a coordinate of the lattice point based on said stored picture signal, and to compute the amount of lens distortion, Said camera is moved to before or the back from said set-up criteria location. The 3rd picture signal store means which stores two or more picture signals photoed and acquired, It constituted so that it might have a lens rectification means to correct said two or more stored picture signals, and a parameter decision means to determine an internal parameter of said camera based on said two or more corrected picture signals, based on said lens distortion center and amount of lens distortion which were computed.

[0010] By this, distortion of an image with a lens can be amended and an internal parameter can be determined correctly. Moreover, it is simple also as a configuration. Furthermore, precision, such as positioning of a work and obstruction detection, can be raised by determining an internal parameter correctly.

[0011]

[Embodiment of the Invention] Hereafter, it is based on an accompanying drawing and the gestalt of implementation of this invention is explained.

[0012] Drawing 1 is the schematic diagram, showing the configuration of the internal parameter decision equipment of the camera concerning this invention on the whole.

[0013] In drawing 1 , a sign 10 shows a camera and a twist concrete target a CCD camera (only henceforth a "camera"). A camera 10 consists of a lens 12 and a main part 14 of a camera. A camera 10 is laid and fixed on a universal head 16.

[0014] As shown in arrow heads 16d, 16e, and 16f, a universal head 16 is constituted so that it may have pivotable, i.e., 6 flexibility, in the circumference of X, Y, and the Z-axis at every several minutes (1/60deg), while being able to consist of X stage 16a, Y stage 16b, and Z stage16c and being able to advance side by side every several micrometers to X, Y, and Z shaft orientations (migration).

[0015] Ahead [of a camera 10 / transverse-plane], a board 18 is arranged. As shown in drawing 2 , grid 18a (40mm (when considering as 1m of clearance) of grid ****) is correctly displayed on a board 18 as a candidate for photography. The incident light from the candidate for photography penetrates a lens 12, and connects an image to the CCD element of the main part 14 of a camera.

[0016] Housing (not shown) is prepared in the lower part of the main part 14 of a camera, and the processing unit 20 which consists of a microcomputer into it is contained. The output (output from a CCD element) of a camera 10 is sent to the processing unit 20 which consists of a microcomputer, and daisy TAIZU of it is carried out by the image input board A/D-conversion processing in it, and it displays an image on the digital image display (not shown) prepared in another object. A digital image display is equipped with the pixel of 640*480. In addition, * shows an asterisk with this specification and drawing.

[0017] Here, a camera (interior) parameter is explained. Drawing 3 is explanatory drawing modeling and showing a camera 10 with a pinhole camera, when photoing grid 18a.

[0018] As shown in drawing 3 , the incident light from the candidate for photography (grid 18a) goes straight on through Focus Og, and ties an image on a CCD side. However, an actual image is distorted and reflected inside (main approach) for a while by distortion of a lens 12 in fact rather than the light which went straight on at this

time. In addition, although it may be distorted to outside approach and may be reflected to it as touched also in advance depending on the lens, below taking the case of the case where it is distorted inside, it explains.

[0019] Drawing 4 is a schematic diagram showing the condition that an image is distorted by distortion of a lens. That is, as shown in drawing 4 , in an image, a straight line curves by distortion of a lens around an image.

[0020] Generally, since the amount of distortion with a lens is decided by distance from an image center, it becomes symmetry to an image center. However, the image center is not necessarily in agreement with the center of the image memory which carried out daisy TAIZU.

[0021] Therefore, when positioning the candidate for photography (body) from an image, it is necessary to determine and take into consideration the distortion center and the amount of distortion of an image with a lens.

[0022] Drawing 5 is explanatory drawing modeling and showing distortion of an image with a lens. In drawing 5 , point O' is the main coordinate of an image memory, and Point O (ox, oy) is the main coordinate of lens distortion.

[0023] Here, if the point acquired by point Pi' (xi', yi') and actual measurement in the theoretical point on the CCD image which distributes proportionally and is obtained from the location on 3D of the photoed point focusing on a focus (point on the image when presupposing that there is no lens distortion) is made into Point Pi (xi, yi), Point Pi will approach Point O (lens distortion center) side from point Pi' by lens distortion. In addition, i means a lattice point number.

[0024] If Point Pi and distance from the lens distortion center O of Pi' are made into r and r', respectively, the above mentioned amount of lens distortion can be expressed like several 1 as a function f of r and r'. Hereafter, this function f is called "function of lens distortion."

[0025]

[Equation 1]

$$f(r, r') = r' - r$$

[0026] Although the function f of lens distortion is decided by layout of a lens, in order to ask by count, it is approximated like several 2 by the polynomial of distance r'.

[0027]

[Equation 2]

$$f(r') = A_1 r' + A_2 r'^2 + A_3 r'^3 + A_4 r'^4 + \cdots$$

ただし、Ai (i = 1, 2, 3, . . .) : 係数

[0028] That is, least-squares approximation of the amount of actually measured distortion is carried out by the polynomial which set the horizontal axis as the

distance from the center of an image, and it asks for each coefficient A 1, A2, A3, and .. Hereafter, this coefficient A i is called "lens distortion coefficient."

[0029] As mentioned above, the relation with the point Pdi (xdi, ydi) [dot] on the image which is an image of the lattice point when the effect by distortion is taken into consideration, in case there are not the point Pg (xg, yg, L) on the three dimension shown in drawing 3 [mm] and lens distortion can be expressed like several 3.

[0030]

[Equation 3]

$$xdi = (1/Xa)\,xi + ox$$
$$= (1/Xa)\cdot(r' - f(r'))/r' * (F/L) * yg + ox$$
$$ydi = (1/Ya)\,yi + oy$$
$$= (1/Ya)\cdot(r' - f(r'))/r' * (F/L) * zg + oy$$

ただし、

$$r' = \sqrt{(xi'^2 + yi'^2)},$$
$$xi' = (F/L)\,yg,\quad yi' = (F/L)\,zg,$$
$$f(r') = A_1 r' + A_2 r'^2 + A_3 r'^3 + A_4 r'^4 + \ldots$$

[0031] Here, as a lattice point number, pixel size with horizontal Xa, and Ya are shown in vertical pixel size and i shows F to drawing 3 like the above, the distance from the CCD side (image pick-up side) at the time of approximating with a pinhole camera to a focus and L are the distance from the candidate for photography to a focus.

[0032] It is the length of the 1-pixel length when thinking that pixel size (Xa, Ya) has the image which carried out daisy TAIZU on a CCD side, and width. This is 1 pixel in not the pixel size of a CCD element but size of the digital image obtained by A/D-conversion processing of an image input board. Therefore, in order to change also with the properties of an A/D circuit besides the pixel size of a CCD element, the specification of CCD camera 10 and measurement determine.

[0033] Even if the lens 12 is using the compound lens which combined two or more lenses and calls it the location of a lens 12, it has remarkable width of face, but a focal location can be decided if approximated with a pinhole camera like drawing 3 .

[0034] However, since it is not the location which the location of this focus also has substance like a CCD side, and can be known from the outside of a camera, measurement determines. Here, it asks as distance [from a photography object to a focus] L [mm].

[0035] However, in the above-mentioned several 3, the lens distortion center coordinate O, the lens distortion function f, pixel size (Xa, Ya), and the focal location Og (or the focal distance L) are all strange.

[0036] Then, the decision technique of each parameter is described below.

[0037] As shown in drawing 4 , a straight line is reflected to a slack type by the image by distortion of a lens around an image. It follows, for example, a horizontal line is photoed, moving a camera 10 up and down, and let a location with least distortion of the vertical direction be Y coordinate oy based on lens distortion [dot]. Moreover, let a location [longitudinal direction] with little distortion similarly be X coordinate ox based on lens distortion [dot]. In case a photograph is taken, the measured lens distortion center position and the center position of a grid are doubled. Moreover, since the amount of distortion [image / including lens distortion] becomes symmetry focusing on distortion, it is adjusting the location and angle of a camera so that the lattice point in the equal distance may become the equal distance from a center also on an image, and makes parallel the grid and image pick-up side for photography.
[0038] Moreover, although the data of the image Pdi of the lattice point in case there are not the lens distortion center coordinate O other than image pick-up data and lens distortion mentioned above is required in order to ask for the function f of lens distortion by several 1 and several 2, at this time, it does not ask other than the coordinate based on lens distortion.
[0039] Then, by the operator, it moves ahead (direction approaching a photography object), and a little location of a camera 10 is photoed. Drawing 6 is explanatory drawing explaining the condition of having moved the location of a camera 10.
[0040] In addition, the image data obtained by the photography before migration is used as "far" data, and the coordinate value on the image of each lattice point on the horizontal axis at that time is made into Xmi'. Similarly the image data obtained after migration is used as "near" data, and the coordinate value on the image of each lattice point on the horizontal axis at that time is made into Xni'.
[0041] If there is no distortion in a lens 12, the relation of a coordinate value Xi to the location Wi of the point on 3D is in proportionality with the inclination decided by the distance L with grid 18a, the amount D of parallel displacements of a camera 10, the focal distance F, and the size Xa of a pixel.
[0042] Drawing 7 is a graphical representation showing the relation between the location on 3D of the lattice point in case there is no distortion, and the location on an image. In addition, the straight line S1 in drawing expresses the proportionality straight line in the case of "being near", and S2 expresses the proportionality straight line in "being far." If this relation specifically "is far" in case there is no lens distortion, and the coordinate value in the case of "being near" are set to Xmi and Xni, it can express like several 4.
[0043]
[Equation 4]

$$Wi = \{(L*Xa)/F\} *Xmi$$
$$= \{(L-D) *Xa/F\} *Xni$$

[0044] in addition — unless it shows clearly especially by the following — a proportionality coefficient — the proportionality coefficient of Wi and Xi — F/(L*Xa) is shown in a "far" case and F/{(L-D) *Xa} is more specifically shown by the case "near."

[0045] However, since it is data with which distortion of an image with a lens 12 was added, that it can measure in the case of an actual camera calibration must calculate the amount of lens distortion from data including this lens distortion.

[0046] Drawing 8 is a graphical representation showing the relation between the location on 3D of a grid when distortion of an image with a lens 12 is added, and the location on an image. The data with which lens distortion joined S1 and S2 is made into S1' and S2'. The data of S1' and S2' is obtained in actual measurement.

[0047] So, the inclination (henceforth a "far" proportionality coefficient) is suitably assigned to a "far" proportionality straight line in case there is no lens distortion, and a twist concrete target. The "far" proportionality straight line is indicated to be S2 to drawing 8 with a dashed line. From the proportionality straight line S2 and measured curvilinear S2', it approximates and asks for function [of lens distortion] f (Xi) by the polynomial of Xi. In addition, by drawing 8 , although the proportionality straight line could be set up how, S2 was set up so that it might become almost equal to the inclination near the zero of S2'.

[0048] Moreover, it should become the same value, also when "near" and the amount of the distortion corresponding to a certain point Xi1 on an image "is far", as shown in drawing 8 since the amount of lens distortion is decided in the location from a lens distortion center. Therefore, function [of this lens distortion] f (Xi) also amends "near" curvilinear S1', and it obtains the proportionality straight line S1.

[0049] On the other hand, the size Xa of a pixel and the distance L between the foci for photography can be found like several 5 which transformed several 4.

[0050]

[Equation 5]

$$L=-D*Xni/(Xmi-Xni)$$
$$Xa=F*Wi*(Xmi-Xni)/(-D*Xni*Xmi)$$

[0051] In drawing 6 , the amount D of parallel displacements of a camera 10, each lattice point "is far" and "near" image coordinate value Xmi' (Xa*X1i), and the location Wi (distance from a center to the lattice point) of the lattice point on Xni' (Xa*X2i) and a three dimension are measurable. Then, it amends using image coordinate value Xmi' including lens distortion, and the function f of the lens distortion

by Xni', and the amended value is set to Xmi and Xni.

[0052] As mentioned above, since a parameter (the parallel displacement distance D, the lattice point location Wi, Xni calculated the account of a top, Xmi) required in order to determine the pixel size Xa and the distance L with the focus for photography can be obtained, L and Xa can be determined from them.

[0053] However, if it asks for Xa and L for every lattice point in fact, since dispersion in Xa of the **** same originally or the value of L is large, it is directly incalculable.

[0054] Then, proportionality coefficient Xni/Wi in the case of "being near" of Wi and Xni of several 4 (inclination of a straight line S1) is set to An, and the value of An is calculated by least-squares approximation using two or more measured value. Similarly, about Xmi, proportionality coefficient Xmi/Wi in the case of "being far" (inclination of S2) is set to Am, and it asks by least-squares approximation from measured value.

[0055] Subsequently, it can substitute for several 6 which did the division of the several 5 right-hand side by Wi (Xa is Wi2), and obtained the proportionality coefficients An and Am for which it asked, and, therefore, can ask for Xa and L.

[0056]

[Equation 6]

$$L = -D * An / (Am - An)$$

$$Xa = F * (Am - An) / (-D * An * Am)$$

[0057] Since the precision of the amount D of parallel displacements of a camera 10 turns into precision of a direct count result so that clearly from several 6, it is necessary to determine in sufficient precision. In addition, the value of Xa and L acquired here is also calculated from the "far" proportionality coefficient set up previously. Such a proportionality coefficient can be freely set up, if it is near the measurement curve of drawing 8 . For example, you may set up so that a proportionality coefficient may be in agreement with the inclination of measured-value curvilinear S2' in a zero, or you may set up so that the sum of the amount of distortion may serve as min.

[0058] Although the above is explanation about the decision technique of the horizontal value Xa of pixel size, it can ask for it by technique with the same said of the vertical value Ya.

[0059] That is, double the main vertical coordinate oy of lens distortion with the center of the perpendicular direction of a grid, and a photograph is taken by carrying out the grid and image pick-up side for photography to parallel by adjusting the location and angle of a camera so that the lattice point which is in the equal distance perpendicularly from a center may become the equal distance also on an image, and

this distance is made into a "far" distance. Moreover, the data of image vertical coordinate Ymi' to the coordinate Wi of the perpendicular direction of a grid is measured from photography data.

[0060] If the coordinate on the image of each grid in case there is no lens distortion is set to Ymi, the relation with the lattice point coordinate Wi on 3D can transform several 4, and can be expressed like several 7.

[0061]

[Equation 7]

$$Wi = \{(L * Ya) / F\} \cdot Ymi$$

[0062] if it elaborates — function f(Xi) =A1 Xi+A2 Xi2+ of a horizontal distortion — since ... is the function of X coordinate, as shown in several 8, it is changed into the function of Y coordinate. However, at this time, since Ya is not calculated yet, the temporary law of the Ya is carried out.

[0063]

[Equation 8]

$$\begin{aligned} g(Yi) &= (Xa/Ya) * f(Yi * (Ya/Xa)) \\ &= (A_1 * Yi\,(Ya/Xa) + A_2 * Yi^2\,(Ya/Xa)^2 \\ &\quad + \ldots) * (Xa/Ya) \\ &= A_1 * Yi + (Ya/Xa) * A_2 * Yi^2 + \ldots \end{aligned}$$

[0064] Proportionality coefficient Ymi/Wi (=F/(L*Ya)) of Wi and Ymi of several 7 is set to Bm, and the value of Bm is calculated by least-squares approximation from two or more measured value like the case of being horizontal. Since the distance L between the foci for photography can already be found, Ya can be determined from the values L and Bm.

[0065] However, since Ya which can be found above is also calculated from Ya which carried out the temporary law previously, it is not necessarily a right value. then, calculated Ya and temporary construction — Ya can be considered to be the right, when the value of Ya of a law is compared and it is in agreement. Therefore, the temporary constant value of Ya is changed suitably and adjusted until it is in agreement.

[0066] Like the above, it can carry out and the distance L between the foci a lens distortion parameter (a lens distortion center position, the amount of lens distortion (or function)), pixel size (Xa, Ya), and for photography can be found as an interior parameter of a camera.

[0067] Subsequently, actuation of the equipment concerning this invention is explained.

[0068] Drawing 9 is the block diagram showing the computational procedure which

asks for a lens distortion center position and a lens distortion function in the equipment shown in drawing 1 . Drawing 10 is a block which shows the computational procedure which finds the distance L of a before [from the size and the photography object of a horizontal pixel / a focus]. Drawing 11 is the block diagram showing the computational procedure which asks for the size of a vertical pixel. The procedures shown in these drawing 9 thru/or drawing 11 are a series of computational procedures.

[0069] Moreover, drawing 12 is a flow chart which shows the same actuation.

[0070] Hereafter, actuation of the equipment concerning this invention is explained, referring to drawing 9 thru/or the drawing 11 block diagram focusing on the drawing 12 flow chart.

[0071] First, the camera 10 which measures an internal parameter in S10 (decision) is installed. Subsequently, it progresses to S12, and the focus of a camera 10 is doubled with grid 18a of a board 18, and it progresses to S14, and asks for a lens distortion center position. Specifically, a center position is determined as follows.

[0072] First, the gap of grid 18a is measured to 0.1 [mm] by eye measure, and a horizontal line is photoed, moving the angle of a camera 10 up and down through an operator's handicraft subsequently.

[0073] Let a segment with least (close to a straight line) distortion of the vertical direction be Y coordinate oy based on lens distortion at this time. Similarly a vertical line is photoed, moving the angle of a camera 10 to right and left, and let a segment with least (close to a straight line) distortion of a longitudinal direction be X coordinate ox based on lens distortion. Thus, the acquired coordinate is set to central point [of lens distortion] O (ox, oy) [dot].

[0074] Subsequently, it progresses to S16, and the center of lens distortion is doubled with the center of grid 18a, and a CCD side is made parallel at grid 18a. Specifically, a center is doubled in the following procedures.

[0075] First, the location and angle of a longitudinal direction are adjusted so that the distance of the grid which is in the equal distance from a main grid, and is near the edge of right and left of an image, and a main grid may be right and left (namely, also in case of in fact) and may become equal also on an image (setting within 0.1 [dot]).

[0076] Subsequently, height and an angle are adjusted and the center of lens distortion is doubled with the center of an aim grid so that the distance of the grid and center which are near the edge similarly may be the upper and lower sides and may become equal also about the vertical direction of an image (less than 0.1 [dot]). Subsequently, it progresses to S18 and grid 18a is photoed.

[0077] In addition, distance of the camera 10 here and grid 18a is made into a "far" distance. Subsequently, it progresses to S20, and predetermined distance migration is

carried out ahead and a camera 10 is photoed in a "near" distance.

[0078] In addition, by actual photography, since a focal distance will change delicately if the focus of a lens 12 is changed, a focus is doubled with a "far" distance and a photograph is taken in a distance "near" as it is. On the tip of a camera 10, and a twist concrete target, the distance D of the tip of a lens 12 and grid 18a is measured at coincidence.

[0079] Subsequently, it progresses to S22, and from the image photoed in a distance "near" and "far", the coordinate of the lattice point on the image is measured, and data-izing in the case of "being "near" and far" and graph-ization are carried out. In addition, in order to equalize the effect of the noise of an analog system etc. in practice, multiple times are photoed in each location and it uses in quest of the value of an average of a lattice point coordinate.

[0080] Subsequently, the horizontal pixel size Xa and the distance L from an aim grid, i.e., the distance between the foci for photography, are computed by it progressing to S24, a proportionality coefficient being set up and progressing to S26, asking for the parameter of a horizontal distortion, progressing to S28, correcting distortion of an image, progressing to S30, calculating a "near" proportionality coefficient from measured value, and progressing to S32.

[0081] The calculation procedure is explained below, referring to drawing 9 and the drawing 10 block diagram.

[0082] Although, as for the image data in the case of "being "near" and far" acquired by processings from S18 to S22, the gap from the image center based on lens distortion is already amended in S16, especially image data here uses what amended the gap of a horizontal direction (the direction of X).

[0083] The image which amended the gap of this lens distortion center is hereafter called main image data. The main image data in the case of "being "near" and far" is shown in drawing 9 and the drawing 10 block diagram with a sign 100,102, respectively.

[0084] For example, if a setup of the proportionality coefficient in the case of "being far" is explained with reference to drawing 9 , a suitable value will be set up in a range where the straight line after distortion amendment is drawn near the measurement curve which shows a "far" proportionality coefficient to drawing 8 in the proportionality coefficient setting section 106. Moreover, it asks for the proportionality image data 110 (lattice point location on an image in case there is no lens distortion) from the real grid data 108 on a three dimension, a gap of a lens distortion center is amended, and it considers as the main proportionality image data 112.

[0085] That is, it asks for the difference of the main image data 100 and the main

proportionality image data 112, and inputs into the function operation part 114 of lens distortion. At the function operation part 114 of lens distortion, the amount of distortion in the distance Xi from the lens distortion center coordinate of each lattice point is calculated, and with the curve passing through a lens distortion center, least-squares approximation is carried out as function [of the distance Xi from a center] f (Xi), and it asks for it.

[0086] in addition, since approximation precision is seldom improved also by the approximate expression to that sufficient precision is acquired as the approximation below about 0.1 [dot], and 7 by the approximate expression to the 3rd order by actual measurement, and the 4th order, approximation to the 3rd order is performed with the gestalt of this operation.

[0087] Subsequently, as shown in drawing 10 , distortion amendment is carried out using function [of lens distortion which was able to obtain the main image data 100,102 in the case of "being "near" and far"] f (Xi), and it considers as the distortion amendment center image data 116,118.

[0088] Subsequently, the center real grid data 122 (Wi) which made the zero the lens distortion center of the distortion amendment center image data 116 (Xmi) and 118 (Xni) and the real grid data 108 is inputted into the proportionality coefficient calculation section 124, and least-squares presumption is carried out and it asks for each proportionality coefficient Am and An in the case of "being "far" and near" in the proportionality coefficient calculation section 124.

[0089] And the distance from the size and the aim grid of a horizontal pixel is found.

[0090] That is, more specifically, the pixel size Xa horizontal from several 6 and the distance L between the foci for photography are computed from the simultaneous equations 126 of the "far" proportionality coefficient Am and the "near" proportionality coefficient An. Since migration length D is known and the distance F between a CCD side and a focus is in Xa and a dependency, it is good at a fixed value.

[0091] If it returns to explanation of drawing 12 , the value subsequently to S34 and S36 acquired spontaneously will be outputted, it will progress to S38 thru/or S46, and the size Ya of a vertical pixel will be determined.

[0092] That is, the temporary law of the size of a vertical pixel is carried out, and it asks for the size of a vertical pixel from a measurement result until the size of a vertical pixel and the size of a count result which carried out the temporary law carry out abbreviation coincidence completely (S38) (from S40 to S46). In addition, "far" image data is used for calculation of vertical pixel size here.

[0093] A sign 200 shows this main image data to drawing 11 . Similarly, let the real grid data which made the vertical lens distortion center the zero be the center real grid

data 202.

[0094] Although obtained previously, since the lens distortion coefficient is the function of the horizontal pixel Xi, it is changed into the function of the vertical pixel Yi. The temporary law of the vertical pixel size Ya is carried out to a proper value, and as shown in several 8, it asks for function [of distortion] g [perpendicular direction] (Yi) from the coefficient of it and a horizontal lens distortion. By function [of distortion] g [perpendicularly / it asked] (Yi), distortion of the main image data 200 is amended, and it considers as the distortion amendment center image data 204.

[0095] From the distortion amendment center image data 204 and the center real grid data 202, the proportionality coefficient Bm of the image perpendicular direction coordinate Yi of the aim grid 18 and the perpendicular direction coordinate Wi on 3D is computed by least-squares presumption in the proportionality coefficient calculation section 206.

[0096] Since the distance L between an aim grid and a focus is acquired previously, according to an equation 208, several 9 [i.e.,], it asks for the size Ya of a vertical pixel using Bm computed by the value L and the above.

[0097]

[Equation 9]

$$Ya = F / (Bm * L)$$

[0098] Ya calculated here is compared with Ya which carried out the temporary law to the proper value previously, and makes true value the value of Ya in case it is judged that it is in agreement. In addition, when it is judged that it is not in agreement, the above-mentioned processings from S36 to S40 are repeated until it is in agreement.

[0099] Then, the value of the size Ya of the pixel of the perpendicularly which it progressed to S48 and was determined like the above is outputted.

[0100] Like the above, the gestalt of this operation is equipment which determines the internal parameter of the camera 10 which includes lens distortion at least. The 1st picture signal store means which stores the picture signal which photos known lattice point pattern 18a, and is acquired (processing unit 20), A lens distortion center calculation means to compute the lens distortion center of said camera based on said stored picture signal (the processing unit 20, S14), It is based on the location of said camera adjusted based on said computed lens distortion center, and a lattice point pattern. A criteria location means to set up the criteria location of said camera (16f from the processing units 20 and 16d, S16), The 2nd picture signal store means which stores the picture signal which photos said lattice point and is acquired from the camera set as said criteria location (the processing unit 20, S18), An amount

calculation means of distortion to compute the amount of lens distortion by measuring the coordinate of the lattice point based on said stored picture signal (the processing unit 20, S26, S42), Said camera is moved to before or the back from said set-up criteria location. The 3rd picture signal store means which stores two or more picture signals photoed and acquired (the processing units 20 and 16a, S20), A lens rectification means to correct said two or more stored picture signals based on said lens distortion center and amount of lens distortion which were computed (the processing unit 20, S28, S44), And it constituted so that it might have a parameter decision means (the processing unit 20, S30, S32, S38, S46) to determine the internal parameter of said camera based on said two or more corrected picture signals.

[0101] Since it constituted like the above, the internal parameter of a camera can be correctly determined by amending distortion of an image with a lens 12. Moreover, it is simple as a configuration. Furthermore, by the ability of the internal parameter of a camera to be determined correctly, also when using for positioning of a work, obstruction detection, etc., precision can be raised.

[0102] In addition, in the above, although the focal distance F was fixed, the size Xa and distance L of a horizontal pixel were found and it subsequently asked for the size Ya of a vertical pixel, the size Xa of a horizontal pixel may be fixed, a focal distance F and distance L may be found according to several 10, and you may ask for the size Ya of a vertical pixel.

[0103]

[Equation 10]

$$L = D * An / (Am - An)$$

$$F = (Xa * D * An * Am) / (Am - An)$$

[0104] Furthermore, the size Ya of a vertical pixel may be fixed, a focal distance F and distance L may be found according to several 11, and, subsequently you may ask for the size Xa of a horizontal pixel.

[0105]

[Equation 11]

$$L = (D * Bn / (Bm - Bn)$$

$$F = (Ya * D * Bn * Bm) / (Bm - Bn)$$

[0106]

[Effect of the Invention] If it is in claim 1 term, an internal parameter can be correctly determined by amending distortion of an image with a lens. Moreover, it is simple as a configuration. Furthermore, by determining an internal parameter correctly, when using for positioning of a work, obstruction detection, etc., precision can be raised.

DESCRIPTION OF DRAWINGS

[Brief Description of the Drawings]

[Drawing 1] It is the schematic diagram, showing the configuration of the internal parameter decision equipment of the camera concerning this invention on the whole.

[Drawing 2] It is explanatory drawing showing the grid (candidate for photography) displayed on the board shown in drawing 1 .

[Drawing 3] It is explanatory drawing modeling and showing the camera shown in drawing 1 with a pinhole camera.

[Drawing 4] It is explanatory drawing showing the condition that an image is distorted by distortion of the lens of the camera shown in drawing 1 .

[Drawing 5] It is model drawing modeling and showing distortion of an image with the lens of the camera shown in drawing 1 .

[Drawing 6] It is explanatory drawing showing migration to the cross direction of the camera shown in drawing 1 .

[Drawing 7] In the camera shown in drawing 1 , it is a graphical representation showing the relation between the location on 3D of the lattice point in case there is no distortion, and the location on an image.

[Drawing 8] In the camera shown in drawing 1 , it is a graphical representation showing the relation between the location on 3D of a grid when distortion of an image with a lens is added, and the location on an image.

[Drawing 9] It is the block diagram showing the computational procedure which asks for the lens distortion center position and lens distortion function which show actuation of the equipment shown in drawing 1 .

[Drawing 10] It is the block diagram showing the computational procedure which finds the distance L of a before [from the size and the photography object of a horizontal pixel in which actuation of the equipment shown in drawing 1 is shown / a focus] which follows drawing 9 .

[Drawing 11] It is the block diagram [showing the computational procedure which asks for the size of a vertical pixel] showing actuation of the equipment shown in drawing 1 which follows drawing 9 .

[Drawing 12] It is the flow chart which shows actuation of the equipment shown in drawing 1 .

[Description of Notations]

10 Camera (CCD Camera)

12 Lens

14 Main Part of Camera

16 Universal Head

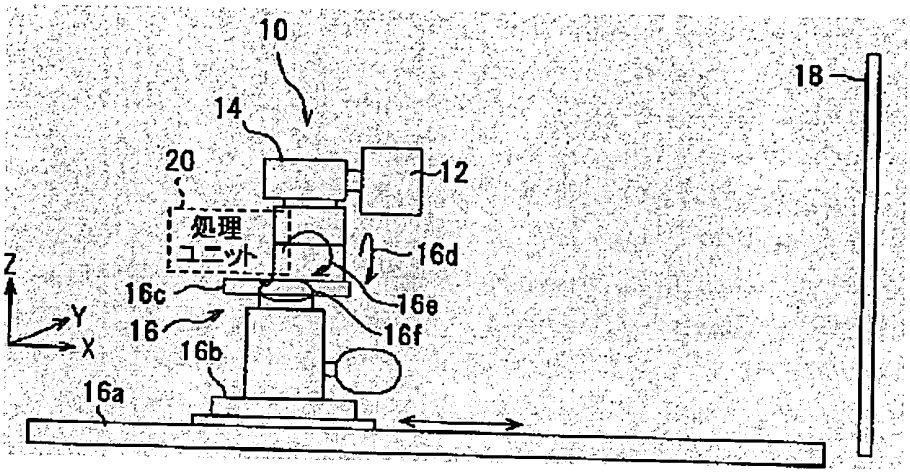
18 Board

20 Processing Unit

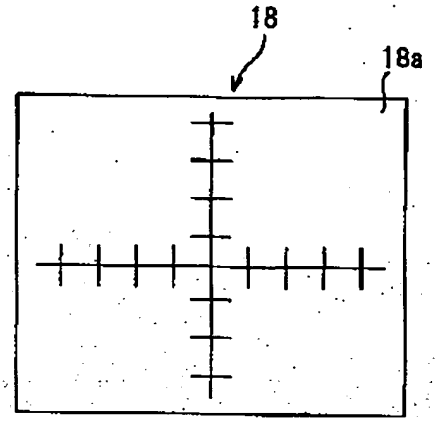
114 Function Operation Part of Lens Distortion

DRAWINGS

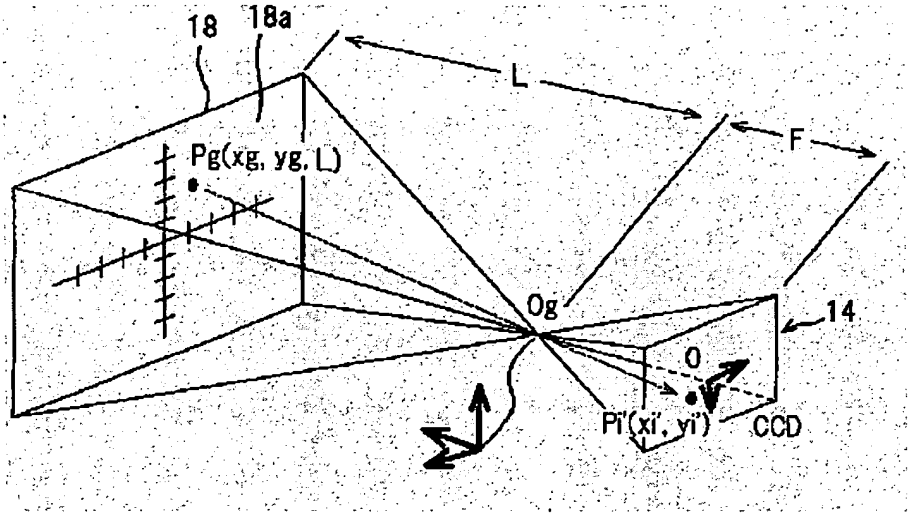
[Drawing 1]



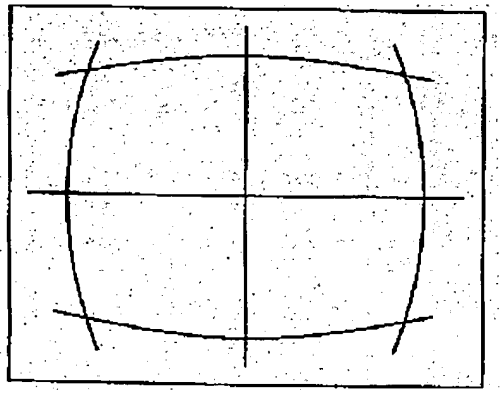
[Drawing 2]



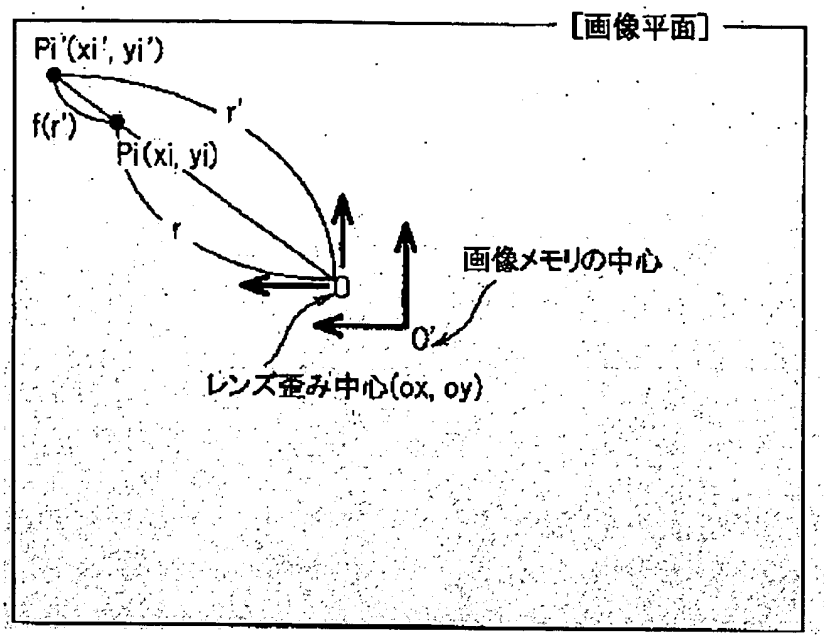
[Drawing 3]



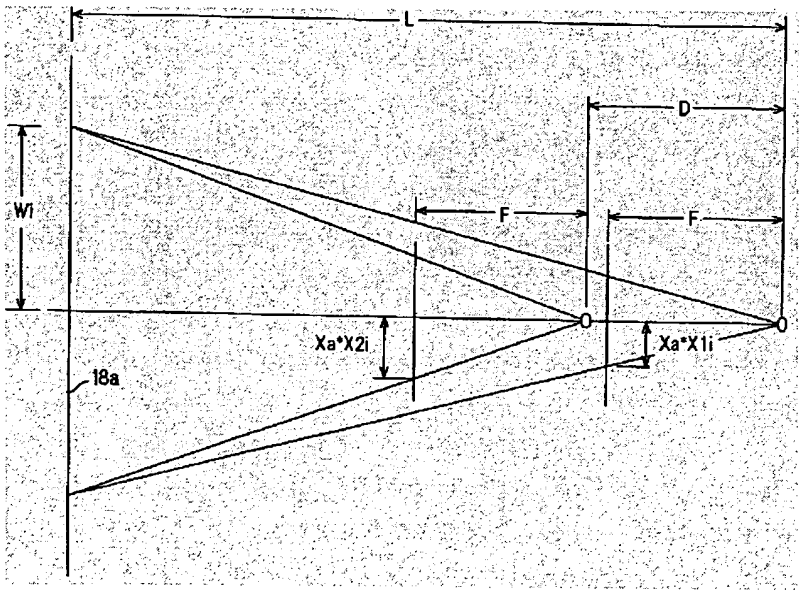
[Drawing 4]



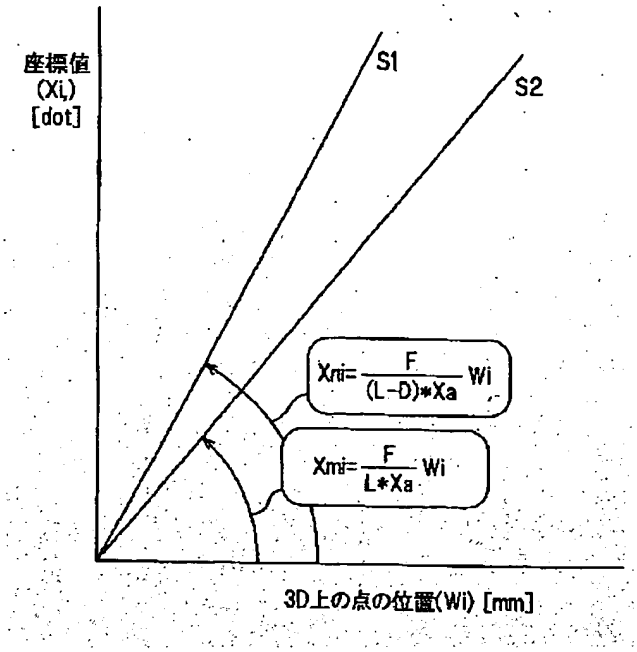
[Drawing 5]



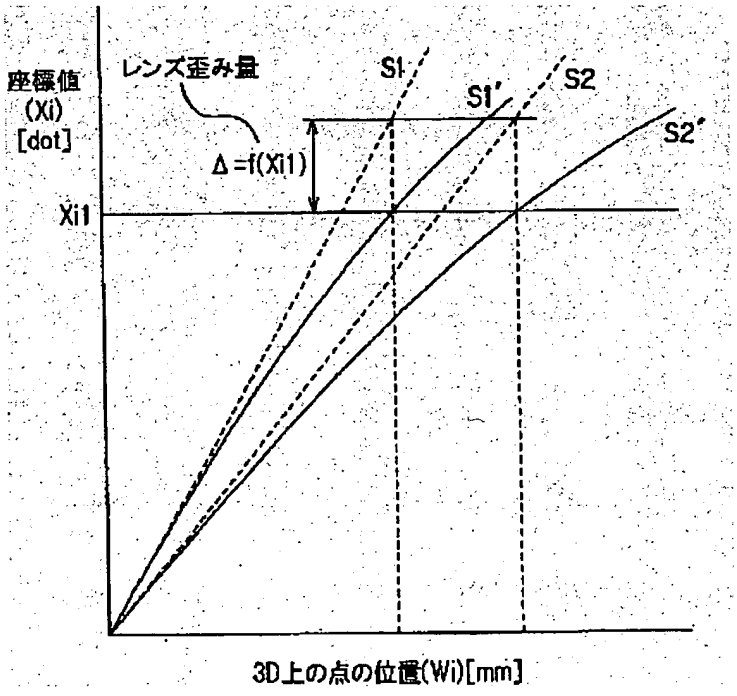
[Drawing 6]



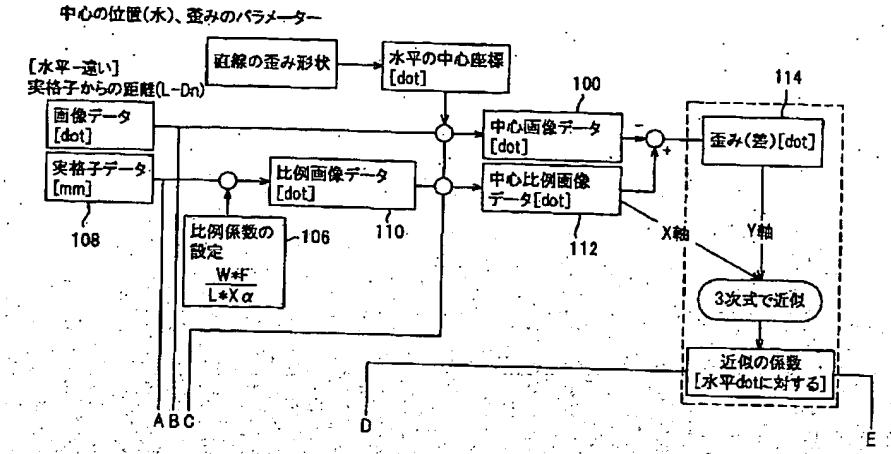
[Drawing 7]



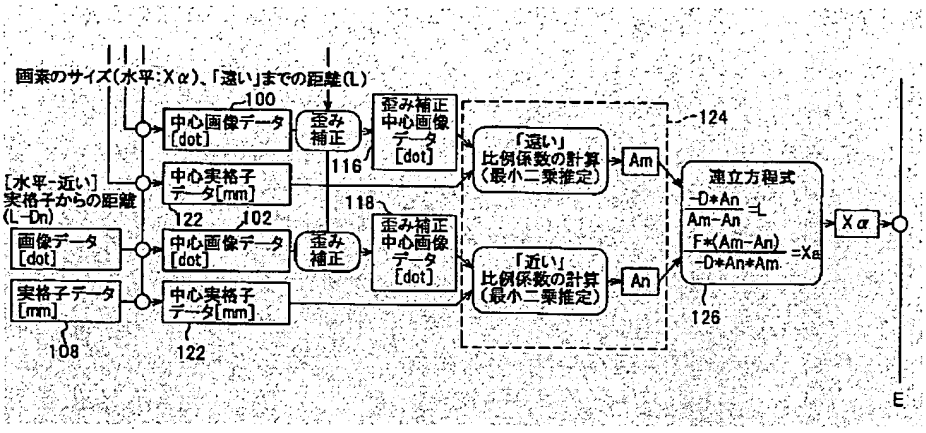
[Drawing 8]



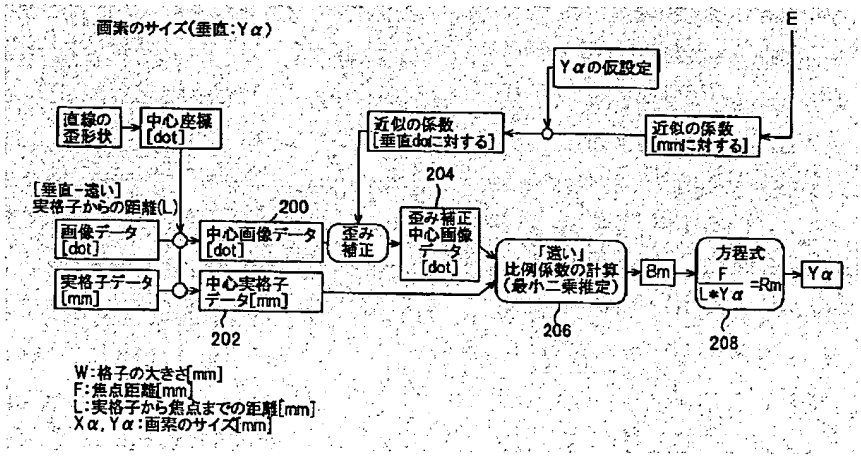
[Drawing 9]



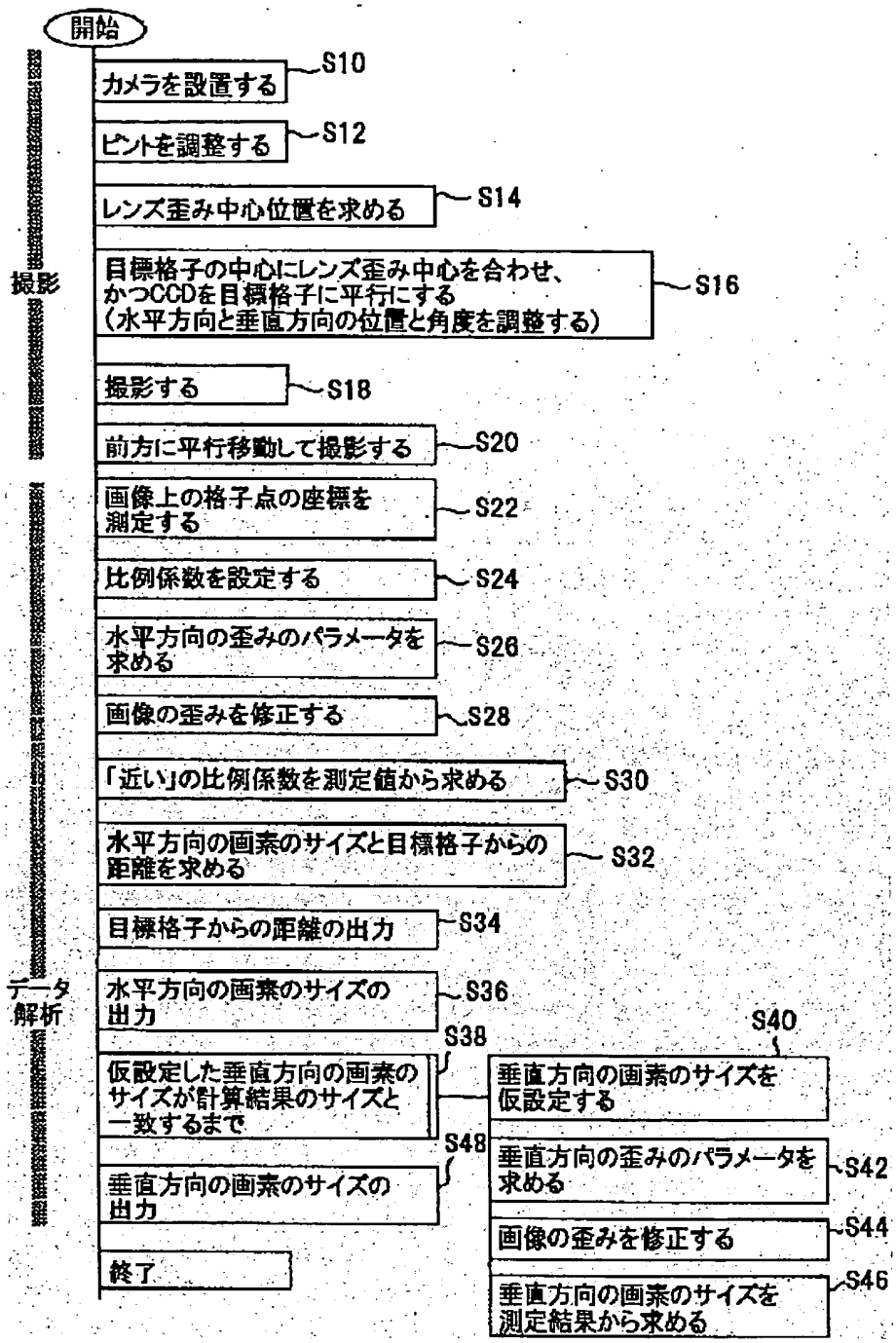
[Drawing 10]



[Drawing 11]



[Drawing 12]


開始
カメラを設置する
S10
ピントを調整する
S12
レンズ歪み中心位置を求める
S14
目標格子の中心にレンズ歪み中心を合わせ、
かつCCDを目標格子に平行にする
(水平方向と垂直方向の位置と角度を調整する)
S16
撮影
撮影する
S18
前方に平行移動して撮影する
S20
画像上の格子点の座標を
測定する
S22
比例係数を設定する
S24
水平方向の歪みのパラメータを
求める
S26
画像の歪みを修正する
S28
「近い」の比例係数を測定値から求める
S30
水平方向の画素のサイズと目標格子からの
距離を求める
S32
目標格子からの距離の出力
S34
データ
解析
水平方向の画素のサイズの
出力
S36
S38
仮設定した垂直方向の画素の
サイズが計算結果のサイズと
一致するまで
S40
垂直方向の画素のサイズを
仮設定する
S48
垂直方向の画素のサイズの
出力
垂直方向の歪みのパラメータを
求める
S42
画像の歪みを修正する
S44
垂直方向の画素のサイズを
測定結果から求める
S46
終了